

# PUEBLO CHEMICAL DEPOT GRASSHOPPER MONITORING: 2002 RESULTS

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## **Executive Summary**

In 1999 the U. S. Fish and Wildlife Service contracted the Colorado Natural Heritage Program (CNHP) to set up a long-term invertebrate monitoring program on Pueblo Chemical Depot (PCD) in Pueblo County, Colorado. The monitoring program was established to detect the influences that vegetation type, grazing disturbance (grazed vs. ungrazed), and recent changes in grazing protocol have on the structure of invertebrate communities. The three habitat types being monitored are greasewood shrubland, shortgrass prairie and sandsage. To detect differences in species composition 32 invertebrate monitoring plots were established in 2000. In 2001, four new plots were incorporated into the monitoring program resulting in a total of 36 plots. Orthopteran species were selected to assess the influences that grazing and vegetation community structure might have on invertebrate community composition. See Sovell (2000) for a discussion of why orthopterans were chosen as the emphasis of this research. In 2001, all 36 invertebrate monitoring plots were sampled four times, once each in May, July, August, and September. To understand annual variation in species composition and density we will measure the permanent plots on an annual basis from May to September through the year 2003.

This report presents the results of the 2002 monitoring season.

## Sampling Objectives

Our primary sampling goal of monitoring grasshopper community structure at PCD is to detect a 20% change at  $P=0.1$  in grasshopper community structure and density over the three years of the project. We are especially interested in the areas where grazing was terminated in late spring of 1998 (i.e., ammunition workshop area and eastern demolition area).

## Methods

### *Study site and disturbance regime*

For information on the study site including general history, location, vegetation, climate and history of livestock grazing see Sovell (2000).

### *Sampling design and data analysis*

The project was designed to sample shortgrass prairie, greasewood shrubland and sandsage shrubland habitat for differences in grasshopper community structure. In addition, the question of whether grazing disturbance influences grasshopper composition was investigated by placing six of the greasewood shrubland plots, four of the shortgrass prairie plots and five of the sandsage plots in areas that experienced past grazing by livestock. For an explanation of how plot locations were chosen see Rondeau (1999). This scheme created six sampling groups consisting of two different grazing regimens (grazed and ungrazed) nested within the three different types of habitat types (shortgrass, greasewood and sandsage).

For an explanation of methodology used to sample vegetation see Rondeau (1999). Percent cover of 21 plant species were summarized into seven vegetation types including shrubs (*Chrysothamnus nauseosus*, *Eriogonum effusum*, *Zinnia grandiflora*), greasewood (*Sarcobatus vermiculatus*) sandsage (*Oligosporus* [*Artemisia*] *filifolius*), cacti (*Opuntia macrorhiza*, *Opuntia polyacantha*, *Opuntia phaeacantha*, *Cylindropuntia imbricata*), native perennial grasses (*Aristida divaricata*, *Aristida purpurea*, *Chondrosum gracile* [*Bouteloua gracilis*], *Hilaria jamesii*, *Sporobolus airoides*, *Sporobolus cryptandrus*, *Stipa comata*), annual native forbs (*Pectis angustifolia*, *Zygophyllum hexagonum*) and noxious weeds (*Bassia* [*Kochia scoparia*] *siever*, *Salsola australis*, *Ipomoea leptophylla*). These seven vegetation types were compared between habitat types and grazing disturbance with Kruskal-Wallis and Wilcoxon signed ranked tests. To explore possible gradients in vegetation composition, all samples were ordinated using detrended correspondence analysis (DCA; Jongman et al. 1995). DCA is an eigenanalysis ordination technique based on reciprocal averaging that ordinales species and samples simultaneously.

Grasshopper community structure was assessed through intensive sweep net collections at every site; sweep samples provide good estimates of relative abundance and species composition (Evans et al. 1983, Evans 1988). As previously stated grasshopper collections were made in May, July, August, and September.

Two transects placed perpendicular to one another and crossing at one end, were used on each plot to estimate grasshopper densities. Each transect consisted of twenty  $0.1\text{m}^2$  hoops (Onsager 1977, 1991; Onsager and Henry 1977) placed 5m apart, creating a transect 100m in length, with a sampling area of  $2\text{m}^2$  per transect or  $4\text{m}^2$  per plot. Densities were estimated by approaching each hoop and counting every grasshopper that jumped or flew from within it. Each hoop was then searched for grasshoppers that did not flee. Individual hoops were treated as subsamples; data from all 40 hoops on each plot were pooled and plots were used as replicate samples (13 greasewood, 12 shortgrass and 11 sandsage). Qualitative estimates of species composition were conducted each monitoring period by intensively sweeping on every plot for a period representing one hour of searching for one individual. All collected grasshoppers were frozen for later identification in the laboratory. To minimize bias in estimates of species composition between sites due to interspecific differences in behavior, whenever possible we caught each grasshopper flushed, regardless of ease of capture (Capinera and Sechrist 1982a). Pinning and identifying the adult grasshoppers determined the species present. Grasshoppers were identified using the keys of Otte (1981 and 1984), Capinera and Sechrist (1982b), Helfer (1987) and Pfadt (1994). Nymphs were omitted from the analysis because of difficulties in identification.

The frequency distribution of hoop sample counts from within each habitat type by grazing disturbance was expected to approximate a Poisson distribution, and so each observed distribution was tested against a Poisson distribution. For all samples a 95% Poisson confidence interval was calculated and samples whose intervals did not overlap were declared different by inspection ( $P$  unspecified, but  $<0.05$ ).

Species richness and evenness were compared between habitat types and grazing disturbance with Kruskal-Wallis and Wilcoxon signed ranked tests. Evenness was calculated using Pielou's (1969) measure [Shannon diversity index  $\div \ln(\text{richness})$ ]. To test for differences in species composition among habitat types and between grazing disturbance types, grasshopper abundance was examined using multi-response permutation procedures (MRPP). MRPP is a nonparametric procedure and thus does not require assumptions associated with alternative parametric tests (multivariate normality and homogeneity of variances; Zimmerman et al. 1985). Euclidian distance and an approximated  $P$ -value from a Pearson type III distribution of the test statistic were used in the MRPP analysis.

The degree of association of individual grasshopper species to specific habitat types or grazing disturbance regime was measured using indicator-species analysis (Dufrene and Legendre 1997). Indicator values, which were calculated for each species and all six combinations of habitat type and grazing disturbance, combine information on relative abundance and relative frequency of occurrence (Schooley et al. 2000). Perfect indication of a habitat (indicator value=100) occurs when all individuals of a species are in one of the habitats, and each sample from that

habitat contains an occurrence of that species. The statistical significance of the maximum indicator value (i.e., highest of the six groups) was tested with Monte Carlo randomization tests (1000 iterations) in which species abundance data were randomized among all 36 study plots.

The MRPP and indicator-species analysis were conducted using PC-ORD (McCune and Mefford 1999). All other statistical analyses were conducted using SAS v.8.01 (SAS institute 1989).

## Results

### *Vegetation Cover*

There were significant differences in vegetation coverage among habitat types (Kruskal-Wallis  $\chi^2=16.8$ ,  $df=5$ ,  $P=0.049$ ) (Fig. 1). Grazing disturbance, however, was not responsible for these differences. For all three habitat types, plant coverage of the seven vegetation types varied little between grazed and ungrazed sites. The only significant difference was a higher cover of other shrubs in the grazed shortgrass prairie habitat (Wilcoxon  $T=31.0$ ,  $P=0.020$ ). Also there is moderate evidence that in grazed greasewood habitats, coverage of noxious weeds was lower (Wilcoxon  $T=36.0$ ,  $P=0.052$ ).

Differences in vegetative cover seem most influenced by habitat type (greasewood, sandsage, or shortgrass prairie). Wilcoxon Two-Sample Tests comparing the seven vegetation types among the three pairs of habitats identified many significant differences (Table 1). Coverage of shrubs other than greasewood and sandsage were lower in shortgrass compared to greasewood ( $T=60.0$ ,  $P<0.001$ ) and sandsage ( $T=65.5$ ,  $P=0.001$ ). As expected, coverage of sandsage was greater in sandsage compared to greasewood ( $T=66.0$ ,  $P<0.001$ ) and shortgrass prairie ( $T=55.0$ ,  $P<0.001$ ), and greasewood samples showed greater coverage of greasewood compared to shortgrass prairie ( $T=55.0$ ,  $P<0.001$ ) and sandsage ( $T=66.0$ ,  $P<0.001$ ). Sandsage samples had greater coverage of cacti compared to greasewood ( $T=90.0$ ,  $P=0.008$ ) and shortgrass prairie ( $T=71.0$ ,  $P=0.003$ ). Finally, sandsage habitats had less cover of both native annual grasses and forbs than did greasewood (grasses:  $T=172.0$ ,  $P=0.001$ ; forbs:  $T=88.0$ ,  $P=0.001$ ) and shortgrass prairie (grasses:  $T=136.0$ ,  $P=0.034$ ; forbs:  $T=82.5$ ,  $P=0.013$ ). There was no difference in plant cover of noxious weeds among the habitat types.

By clearly separating the three habitat types (Fig 2), DCA ordination of the seven vegetation types supported the validity of the results of the nonparametric analysis presented above. In addition, vegetation types responsible for structuring the ordination (Pearson  $r \geq 0.463$ ) were identified by Wilcoxon Two Sample Tests as differing significantly among habitats (Fig. 2, Table 1). Also, an effect of grazing disturbance was not evident in the structure of the DCA ordination (Fig. 2), further supporting the results of the nonparametric analysis.

### *Grasshopper Species Composition*

1839 grasshoppers were identified to species from collections made during 2002 (Table 2). Thirty five species of grasshoppers were identified from 24 genera and five families. *Melanoplus* (four species) was the most species-rich genus and the four most numerous species were *Eritettix simplex*, *Psoloessa delicatula*, *Psoloessa texana*, and *Trimerotropis pallidipennis*. Obligate grass feeders were the most abundant grasshoppers collected followed closely by mixed feeders, comprising 66% and 23% respectively of the total sample (Table 3). Obligate forb feeders comprised less than 1% of the total sample.

Analysis of grasshopper samples did not identify significant differences in grasshopper species richness (Kruskal-Wallis  $\chi^2=1.81$ ,  $df=2$ ,  $P=0.4055$ ) or species evenness (Kruskal-Wallis  $\chi^2=3.15$ ,  $df=2$ ,  $P=0.2068$ ) among study plots. There were no significant differences identified in species richness between greasewood and shortgrass habitats (Kruskal-Wallis  $\chi^2=0.061$ ,  $df=1$ ,  $P=0.8043$ ), greasewood and sandsage habitats (Kruskal-Wallis  $\chi^2=0.829$ ,  $df=1$ ,  $P=0.3625$ ), or shortgrass and sandsage habitats (Kruskal-Wallis  $\chi^2=1.850$ ,  $df=1$ ,  $P=0.1738$ ). In addition, there were no significant differences identified in evenness between greasewood and shortgrass habitats (Kruskal-Wallis  $\chi^2=1.183$ ,  $df=1$ ,  $P=0.2767$ ), greasewood and sandsage habitats (Kruskal-Wallis  $\chi^2=2.761$ ,  $df=1$ ,  $P=0.0966$ ), or shortgrass and sandsage habitats (Kruskal-Wallis  $\chi^2=0.806$ ,  $df=1$ ,  $P=0.3692$ ).

MRPP analysis of the six groups of habitat type by grazing disturbance revealed that grasshopper species composition differed among treatment groups in May/June ( $T=-22.1$ ,  $A=0.3472$ ,  $P<0.0001$ ,  $n=6$ ), July ( $T=-12.7$ ,  $A=0.3768$ ,  $P<0.0001$ ,  $n=6$ ), August ( $T=-9.8$ ,  $A=0.2762$ ,  $P<0.0001$ ,  $n=6$ ), and September ( $T=-3.6$ ,  $A=0.1037$ ,  $P<0.0025$ ,  $n=6$ ); as well as cumulatively ( $T=-9.7$ ,  $A=0.4529$ ,  $P<0.0001$ ,  $n=6$ ). Differences in grasshopper community structure were then examined between the three habitat types and the two grazing treatments. This analysis revealed significant differences in grasshopper composition between greasewood samples and both sandsage ( $T=-13.3$ ,  $A=0.4591$ ,  $P<0.0001$ ,  $n=2$ ) and shortgrass prairie samples ( $T=-14.0$ ,  $A=0.4362$ ,  $P<0.0001$ ,  $n=2$ ), as well as significant differences between sandsage and shortgrass prairie samples ( $T=-12.1$ ,  $A=0.3653$ ,  $P<0.0001$ ,  $n=2$ ). There were no significant differences in grasshopper community structure between grazed and ungrazed samples within any of the three habitat types (shortgrass prairie:  $T=-0.8$ ,  $A=0.0398$ ,  $P=0.1909$ ; sandsage:  $T=-1.1$ ,  $A=0.059$ ,  $P=0.8899$ ; greasewood:  $T=-0.4$ ,  $A=0.0247$ ,  $P=0.2657$ ; all  $n=2$  groups). Four of the study plots were currently subjected to grazing by either cattle or prairie dogs. When these four plots were compared to the other 32 plots using the MRPP, significant differences in grasshopper community structure were identified ( $T=-2.3$ ,  $A=0.0514$ ,  $P=0.0334$ ,  $n=2$ ).

## **Discussion**

Vegetative cover differed significantly among the habitat types, whereas grazed and ungrazed samples differed little. Cover of sagebrush in sandsage and greasewood in greasewood shrubland were characteristically greater. In addition, on sandsage there was significantly more cacti whereas cover of native grasses and forbs was low. Finally, the percent cover of shrubs other than sagebrush and greasewood was lower on the shortgrass prairie habitats. This all points to strong differences in vegetative structure on the three different habitat types. There were noticeable differences in cover between grazed and ungrazed areas, but these differences were lower in magnitude than those found among the three habitat types. The most noteworthy difference is that percent cover of other shrubs is greater on shortgrass prairie areas that have been grazed. This is particularly interesting when considering that the percent cover of other shrubs is in general lower on shortgrass prairie habitats. This suggests that grazing may have increased cover of other shrubs on shortgrass prairie. That this difference influenced grasshopper species composition is supported by the analysis of grasshopper abundance.

Grasshopper community structure was strongly affected by temporal variation throughout the sampling season as indicated by the MRPP analysis. This is primarily due to the differing life cycles of the various grasshopper species found in this area. It is also evident that the vegetation mosaic created by the patchy distribution of shortgrass prairie, greasewood and sandsage throughout this landscape strongly influences grasshopper community structure. While no differences in community structure were identified between the original grazed and ungrazed treatments within each habitat type, the community structure of the four plots currently subjected to grazing by cattle or prairie dogs differed significantly from the 32 plots not grazed since 1998. Unsurprisingly, shortgrass prairie areas had a significantly greater numbers of obligate grass-feeding species than did sandsage areas (Table 3). In contrast, sandsage areas had significantly greater numbers of mixed feeding species than did shortgrass prairie areas (Table 3).

These analyses are based upon samples collected during the months of May, July, August, and September in 2002. In contrast to the 2000 season, when samples were only collected in August and September, the 2001 and 2002 collections suggests that sampling throughout the late-spring and summer months is the most beneficial approach for this study due to the high temporal variability in grasshopper species composition. This approach will also allow analysis of data across multiple years and allow for comparison with annual trends in vegetation, which may yield more informative results.

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## Literature Cited

- Baldi, A. and T. Kisbenedek. 1997. Orthopteran assemblages as indicators of grassland naturalness in Hungary. *Agriculture, Ecosystem & Environment*. 66: 121-129.
- Capinera, J.L and T.S. Sechrist. 1982a. Grasshopper (Acrididae) - host plant associations: Response of grasshopper populations to cattle grazing intensity. *Canadian Zoologist*. 114: 1055-1062.
- Capinera, J.L and T.S. Sechrist. 1982b. Grasshoppers (Acrididae) of Colorado: Identification, biology and management. Colorado State University Experiment Station, Fort Collins, Bulletin No. 584S. 161pp.
- Dufrene, M. and P. Legendre. 1997. Species assemblages and indicator species: The need for a flexible asymmetrical approach. *Ecological Monographs*. 67: 345-366.
- Evans, E.W. 1988. Grasshopper (Insecta: Orthoptera: Acrididae) assemblages of tallgrass prairie: Influences of fire frequency, topography and vegetation. *Canadian Journal of Zoology*. 66: 1495-1501.
- Evans, E.W., R.A. Rogers and D.J. Opfermann. 1983. Sampling grasshopper (Orthoptera: Acrididae) on burned and unburned tallgrass prairie: Night trapping vs. sweeping. *Environmental Entomology*. 12: 1449-1454.
- Fielding, D.J. and M.A. Brusven. 1993. Grasshopper (Orthoptera: Acrididae) community structure and ecological disturbance on southern Idaho rangeland. *Environmental Entomology*. 22: 71-81.
- Fischer, F. P., U. Schulz, H. Schubert, P. Knapp and M. Schmoger. 1997. Quantitative assessment of grassland quality: Acoustic determination of population sizes of orthopteran indicator species. *Ecological Applications*. 7: 909-920.
- Helfer, J. R. 1987. How to know the grasshoppers, crickets, cockroaches and their allies. Dover Publications inc., New York. 363.
- Jepson-Innes, K. and C.E. Bock. 1989. Response of grasshoppers (Orthoptera: Acrididae) to livestock grazing in southeastern Arizona: Differences between seasons and subfamilies. *Oecologia*. 8: 430-431.
- Jongman, R. H. G., C.J.F. ter Braak and O. F. R. van Tongeren. 1995. Data analysis in community and landscape ecology. Cambridge University Press, Cambridge, UK.



- Kemp, W.P., S.J. Harvey and K.M. O'Neil. 1990. Patterns of vegetation and grasshopper community composition. *Oecologia*. 83: 299-308.
- McCune, B. and M.J. Mefford. 1999. PCORD. Multivariate analysis of ecological data. Version 4.0 MjM Software Design, Gleneden Beach, Ore.
- Meffe, G.K and C.R. Carrol. 1994. Principles of conservation biology. Sinauer Associates, Sunderland, MA.
- Onsager, J.A. 1977. Comparison of five methods for estimating density of rangeland grasshoppers. *Journal of Economic Entomology*. 70: 187-190.
- Onsager, J.A. 1991. Toward an optimum for estimating density of grasshopper (Orthoptera: Acrididae) from a Poisson distribution. *Environmental Entomology*. 20: 939-944.
- Onsager, J.A. and J.E. Henry. 1977. A method for estimating the density of rangeland grasshoppers (Orthoptera: Acrididae) in experimental plots. *Acrida*. 6:231-237.
- Otte, D. 1981. The North American Grasshoppers: Volume I (Acrididae/Gomphocerinae and Acridinae. Harvard University Press, Cambridge, Massachusetts. 275pp.
- Otte, D. 1984. The North American Grasshoppers: Volume II (Oedipodinae)). Harvard University Press, Cambridge, Massachusetts. 366pp.
- Parajulee, M.N., J.E.. Slosser, R. Montandon, L. Dowhower and W.E. Pinchak. 1997. Rangeland grasshoppers (Orthoptera: Acrididae) associated with mesquite and juniper habitats in the Texas rolling plains. *Community and Ecosystem Ecology*. 26: 529-536.
- Pearson, D.L. 1994. Selecting indicator taxa for the quantitative assessment of biodiversity. *Philosophical Transactions of the royal Society of London Ser. B* 345, 75-79.
- Pfadt, R.E. 1994. Field guide to common western grasshoppers. Wyoming Agricultural Experiment Station, Bulletin 912, September 1994. 42pp.
- Pielou, E.C. 1969. An introduction to mathematical ecology. Wiley, New York.
- Quinn, M.A., R.L. Kepner, D.D. Walgenbach, R.A. Bohls and P.D. Pooler. 1991. Habitat characteristics and grasshopper community dynamics on mixed-grass rangeland. *Canadian Entomologist*. 123: 89-103.

- Rondeau, R. 1999. Pueblo Chemical Depot vegetation monitoring: 1999 results. Colorado Natural Heritage Program, Colorado State University, Fort Collins, Colorado.
- SAS Institute. 1989. SAS/STAT user's guide, version 6, 4<sup>th</sup> edn. SAS Institute, Cary, N. C.
- Schooley, R.L., B.T. Bestelmeyer, and J.F. Kelly. 2000. Influence of small-scale disturbance by kangaroo rats on Chihuahuan Desert ants. *Oecologia*. 125: 142-149.
- Shure, D.J. and D.L. Phillips. 1991. Patch size of forest openings and arthropod populations. *Oecologia*. 86: 325-334.
- Sovell, J.R. 2000. Pueblo Chemical Depot grasshopper monitoring: 1999 results. Colorado Natural Heritage Program.
- Zimmerman, G.M., H. Goetz and P.W. Mielke Jr. 1985. Use of an improved statistical method for group comparison to study effects of prairie fire. *Ecology*. 66: 606-611.

Table 1. Correlation of three habitat types (greasewood, shortgrass prairie and sandsage) on plant cover of seven vegetation types. Wilcoxon Two-Sample Tests were used to compare vegetation cover for all possible pairs of habitat types (greasewood-shortgrass prairie, greasewood-sandsage and shortgrass prairie-sandsage). Indicated differences for a specific habitat type are in comparison to the other two habitat types.

Vegetation Type	Habitat Type – Significant Differences <sup>1</sup>		
	Greasewood	Shortgrass Prairie	Sandsage
Other shrub		less**	
Sandsage			greater**
Greasewood	greater***		
Cacti	greater**(than shortgrass)		greatest*
Native annual grasses		less*	
Native annual forbs		less*	
Noxious weeds <sup>2</sup>			

1 \*  $P \leq 0.05$ ; \*\*  $P \leq 0.001$ ; \*\*\*  $P \leq 0.0001$

2 There are no significant differences in plant cover of noxious weeds for any pair of habitat types

Table 2. List of orthopteran species and their abundances given as number of individuals/habitat. SGUG: shortgrass ungrazed; SGG: shortgrass grazed; SSUG: sandsage ungrazed; SSG: sandsage grazed; GWUG; greasewood ungrazed; GWG: greasewood grazed; OF: obligate forb; OG: obligate grass; MF: mixed feeder. ?: Unknown feeder. \* Species with significant indicator values ( $P \leq 0.05$ ).

ORTHOPTERIDEA SPECIES	SPP. CODE	FEEDING CAT.	Sites															
			GWG				GWUG				SGG				SGUG			
			May/ June	July	Aug	Sept	May/ June	July	Aug	Sept	May/ June	July	Aug	Sept	May/ June	July	Aug	Sept
Gomphocerinae (Slantfaced)																		
<i>Ageneotettix deorum</i>	AD	OG	0	0	2	0	0	0	0	0	0	0	0	2	0	0	0	3
<i>Amphitornus coloradus</i>	AC	OG	0	11	0	1	0	6	1	0	0	1	0	1	0	0	2	1
<i>Aulocara femoratum</i>	AF	OG	0	0	0	1	0	2	0	0	0	2	1	3	0	2	2	1
<i>Cordillacris crenulata</i>	CC	OG	0	2	2	0	0	2	0	0	0	14	9	2	0	8	6	2
<i>Cordillacris occipitalis</i>	CO	OG	4	23	2	0	1	13	0	0	3	11	0	0	0	4	2	0
<i>Eritettix simplex</i>		OG	71	38	0	0	82	62	1	0	29	6	0	0	23	19	2	0
<i>Mermiria bivittata</i>	MeB	OG	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0
<i>Opeia obscura</i>	OO	OG	0	0	19	2	0	0	20	11	0	0	6	15	0	0	15	4
<i>Paropomala pallida</i>	PP	OG	0	0	2	0	0	0	2	0	0	0	1	0	0	0	0	0
<i>Paropomala wyomingensis</i>	PW	OG	0	18	12	1	0	4	5	1	0	19	11	1	0	2	4	0
<i>Phlibostroma quadrimaculatum</i>	PQ	OG	0	0	1	0	0	0	1	2	0	0	2	3	0	0	0	2
<i>Psoloessa delicatula</i>		OG	11	7	0	0	7	7	0	0	37	20	1	0	55	22	0	1
<i>Psoloessa texana</i>		?	1	0	11	6	0	2	8	7	0	2	7	5	1	1	7	3
Oedipodinae (Bandwinged)																		
<i>Arphia conspersa</i>	AR	MF	7	1	0	0	10	0	0	0	6	1	0	0	6	0	0	0
<i>Arphia pseudonietana</i>	AP	MF	0	0	0	2	0	0	1	4	0	0	1	1	0	0	1	0
<i>Arphia Simplex</i>		MF	4	0	0	0	3	0	0	0	1	0	0	0	1	0	0	0
<i>Hadrotettix trifasciatus</i>	HT	MF	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	2
<i>Mestobregma plattei</i>	MeP	?	0	0	16	2	0	0	10	4	0	0	8	11	0	0	4	5
<i>Spharagemon collare</i>	SC	MF	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Spharagemon equale</i>	SE	MF	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Trachyrhachys aspera</i>	TA	OG	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	1

Table 2 (con't)

			Sites								
			SSG				SSUG				Species Total
ORTHOPTERIDEA SPECIES	SPP. CODE	FEEDING CAT.	May/ June	July	Aug	Sept	May/ June	July	Aug	Sept	
Gomphocerinae (Slantfaced)											
<i>Ageneotettix deorum</i>	AD	OG	0	0	0	0	0	0	0	1	8
<i>Amphitornus coloradus</i>	AC	OG	0	3	1	0	0	4	0	0	21
<i>Aulocara femoratum</i>	AF	OG	0	0	0	0	0	2	0	0	16
<i>Cordillacris crenulata</i>	CC	OG	0	6	0	0	0	0	1	0	52
<i>Cordillacris occipitalis</i>	CO	OG	3	23	3	0	0	22	2	2	91
<i>Eritettix simplex</i>		OG	4	0	0	0	14	0	0	0	242
<i>Mermiria bivittata</i>	MeB	OG	0	0	0	0	0	2	0	0	4
<i>Opeia obscura</i>	OO	OG	0	0	0	1	0	0	2	2	97
<i>Paropomala pallida</i>	PP	OG	0	4	18	3	0	4	19	9	62
<i>Paropomala wyomingensis</i>	PW	OG	0	3	6	1	0	17	3	2	92
<i>Phlibostroma quadrimaculatum</i>	PQ	OG	0	0	0	0	0	0	0	0	11
<i>Psoloessa delicatula</i>		OG	50	4	1	0	58	4	0	0	267
<i>Psoloessa texana</i>		?	17	29	4	3	14	29	4	4	164
Oedipodinae (Bandwinged)											
<i>Arphia conspersa</i>	AR	MF	10	0	0	0	14	0	0	0	47
<i>Arphia pseudonietana</i>	AP	MF	0	0	0	0	0	0	0	0	10
<i>Arphia Simplex</i>		MF	1	0	0	0	2	0	0	0	12
<i>Hadrotettix trifasciatus</i>	HT	MF	0	0	0	0	0	0	0	0	3
<i>Mestobregma plattei</i>	MeP	?	0	0	3	1	0	0	1	5	70
<i>Spharagemon collare</i>	SC	MF	0	0	2	1	0	0	0	0	3
<i>Spharagemon equale</i>	SE	MF	0	0	2	0	0	0	7	0	10
<i>Trachyrhachys aspera</i>	TA	OG	0	0	0	0	0	0	0	0	3

Table 2 (con't)

ORTHOPTERIDEA SPECIES	SPP. CODE	FEEDING CAT.	Sites															
			GWG				GWUG				SGG				SGUG			
			May/June	July	Aug	Sept	May/June	July	Aug	Sept	May/June	July	Aug	Sept	May/June	July	Aug	Sept
<i>Trimerotropis pallidipennis</i>	TP	MF	0	16	9	2	0	15	6	9	0	7	9	11	0	28	11	8
<i>Xanthippus corallipes</i>	XC	OG	5	0	0	0	4	1	0	0	9	9	0	0	7	6	1	0
Melanoplinae (Spurthroated)																		
<i>Aeoloplides turnbulli</i>	AT	OF	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0
<i>Dactylotum bicolor</i>	DB	OF	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0
<i>Hesperotettix viridis</i>	HV	OF	0	3	0	0	0	1	0	0	0	0	0	0	0	0	0	0
<i>Melanoplus bowditchi</i>		MF	0	0	1	0	0	0	0	3	0	2	0	0	0	0	0	0
<i>Melanoplus confusus</i>	MB	OF	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
<i>Melanoplus occidentalis</i>	ML	MF	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
<i>Melanoplus sanguinipes</i>	MP	MF	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	0
<i>Melanoplus spp.</i>	MS	MF	0	1	0	0	1	0	1	1	0	1	1	1	0	3	0	0
Cyrtacanthacridinae																		
<i>Schistocerca alutacea</i>		OF	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Acrididae (short-horned)																		
<i>Dissosteira Longipennis</i>			0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
<i>Lepus Intermedius</i>			0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
<i>Unkown</i>			0	0	0	0	0	1	0	0	0	1	6	3	0	0	0	0
Total Species Collected			103	121	79	17	110	120	57	43	85	106	65	60	93	98	62	31

Table 2 (con't)

Table 2 (cont.)

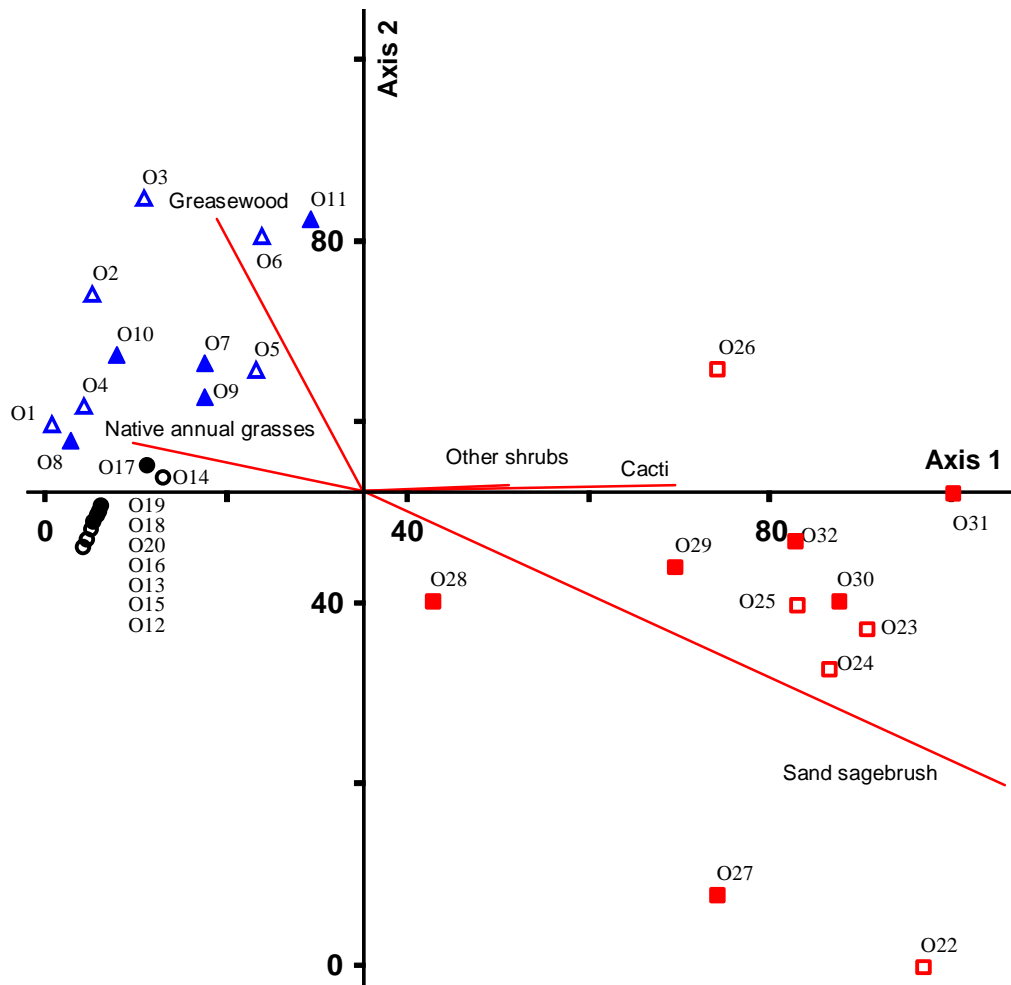
			Sites								
			SSG				SSUG				Species Total
ORTHOPTERIDEA SPECIES	SPP. CODE	FEEDING CAT.	May/J une	July	Aug	Sept	May/ June	July	Aug	Sept	
<i>Trimerotropis pallidipennis</i>	TP	MF	1	4	3	3	0	11	3	3	143
<i>Xanthippus corallipes</i>	XC	OG	6	4	0	0	10	1	1	0	59
Melanoplinae (Spurthroated)											
<i>Aeoloplides turnbulli</i>	AT	OF	0	0	0	0	0	0	0	0	4
<i>Dactylotum bicolor</i>	DB	OF	0	0	0	0	0	0	0	0	2
<i>Hesperotettix viridis</i>	HV	OF	0	0	0	0	0	0	1	0	5
<i>Melanoplus bowditchi</i>		MF	0	17	9	0	0	12	10	4	58
<i>Melanoplus confusus</i>	MB	OF	0	0	0	0	0	0	0	0	2
<i>Melanoplus occidentalis</i>	ML	MF	0	4	0	0	0	4	0	0	9
<i>Melanoplus sanguinipes</i>	MP	MF	0	0	0	0	0	0	0	0	4
<i>Melanoplus spp.</i>	MS	MF	1	0	5	3	1	3	2	3	27
Cyrtacanthacridinae											
<i>Schistocerca alutacea</i>		OF	0	0	1	0	0	0	0	0	1
Acrididae (short-horned)											
<i>Dissosteira Longipennis</i>			0	0	0	0	0	0	0	0	1
<i>Lepus Intermedius</i>			0	0	0	0	0	0	0	0	1
<i>Unkown</i>			0	0	0	0	0	0	0	0	11
Total Species Collected			93	101	58	16	113	115	56	35	1839

Table 3. Summary of grasshopper abundance by feeding and habitat classification, and grazing disturbance.

Habitat Classification*	Feeding Type				
	Obligate Grass	Obligate Forb	Mixed Feeder	Unknown	Totals
SGUG	528	24	215	35	802
SGG	469	27	232	88	816
SSUG	254	33	511	78	876
SSG	225	23	465	24	737
GWUG	408	60	356	23	847
GWG	384	49	290	64	787
Totals	2268	216	2069	312	4865

\* Habitat classifications are as defined in Table 1.





**Figure 2** Detrended correspondence analysis ordination joint plot of 32 study plots based on the percent cover of 7 vegetation types and percent canopy cover for those vegetation types most responsible for structuring the ordination. Lines indicate directions that corresponding plant species abundances increases most, and line length is proportional to the rate of that change. Disturbance categories are indicated by symbols: ▲ greasewood ungrazed N=5; ▲ greasewood grazed N=6; ● shortgrass ungrazed N=5; ● shortgrass grazed N=4; ■ sandsage ungrazed N=6; ■ sandsage grazed N=5. Site codes: greasewood grazed (O1-O6); greasewood ungrazed (O7-O11); shortgrass grazed (O12-O15); shortgrass ungrazed (O16-O21); sandsage grazed (O22-O26); sandsage ungrazed (O27-O32).